[SPECIFICATION]

[Title of the Invention]

PHASE EDGE PHASE SHIFT MASK ENFORCING WIDTH OF FIELD GATE IMAGE AND FABRICATION METHOD THEREOF

[Brief Description of the Drawings]

The above and other objects and advantages of the present invention will become readily apparent from the description that follows, with reference to the accompanying drawings, in which:

Fig. 1a is a portion of rough diagram of a phase shift mask according to a phase edge phase shift mask of prior art.

Fig. 1b is a rough image pattern of a phase shift mask formed on a semiconductor substrate according to a phase edge phase shift mask of prior art.

Fig. 1c is a portion of rough diagram of a trim mask according to a phase edge phase shift mask of prior art.

Fig. 1d is a rough image pattern of a trim mask formed on a semiconductor

substrate according to a phase edge phase shift mask of prior art.

Fig. 2a is a phase edge phase shift mask according to one embodiment of the present invention, illustrating a portion of rough diagram of a trim mask overlapped with shifters.

Fig. 2b is one embodiment according to a phase edge phase shift mask of the present invention, illustrating rough images formed by a phase shift mask and a trim mask on a semiconductor substrate.

Fig. 2c is comparison data with one embodiment according to a phase edge phase shift mask of the present invention, illustrating a portion of wiring diagram formed by a phase edge phase shift mask of prior art.

Fig. 2d is comparison data with one embodiment according to a phase edge phase shift mask of the present invention, illustrating an image picture after photo simulation on a phase edge phase shift mask of prior art.

Fig. 2e is one embodiment according to a phase edge phase shift mask of the

present invention, illustrating a portion of wiring diagram formed by the phase edge phase shift mask.

Fig. 2f is one embodiment according to a phase edge phase shift mask of the present invention, illustrating an image picture after photo simulation.

Fig. 3a is a phase edge phase shift mask according to another embodiment of the present invention, illustrating a trim mask overlapped with shifters.

Fig. 3b is another embodiment according to a phase edge phase shift mask of the present invention, illustrating rough images formed by a phase shift mask and a trim mask on a semiconductor substrate.

Fig. 3c is a phase edge phase shift mask according to another embodiment of the present invention, illustrating a portion of wiring diagram formed by a phase edge phase shift mask.

Fig. 3d is another embodiment according to a phase edge phase shift mask of the present invention, illustrating an image picture after photo simulation.

[Detailed Description of the invention]

[Object of the Invention]

[Technical field of the Invention and Related Art prior to the Invention]

The present invention generally relates to a phase edge phase shift mask, and more specifically, to a phase edge phase shift mask enforcing a width of a field gate image located in a field region of a semiconductor substrate and a fabrication method thereof.

Recently, an exposing method to a semiconductor substrate by a quartz mask board with the use of chromium causes optical interference between neighboring patterns owing to reduction in a design rule of a semiconductor device, thereby making it difficult to obtain desirable pitch sizes.

As a substitute, a phase shift mask implementing precise and detailed patterns by reducing optical interference between the neighboring patterns on the semiconductor substrate with the use of chromium and molybdenum on the quartz mask board has been fabricated. It is a recent trend to use more than one phase shift mask to implement sizes required at a design. And, a phase edge phase shift mask having a masking technique used for exposure in combination with a phase mask becomes influential.

For instance, a phase edge phase shift mask technology described above is shown in the United States Patent No. 5,807,649(Lars W. Liebmann). According to the United States Patent No. 5,807,649, two masks are used to form the same patterns as gate electrodes on a semiconductor substrate. The two masks are composed of a phase shift mask and a trim mask.

Generally, the phase shift mask defines a predetermined part of a photoresist image overlapping on an active region of the semiconductor substrate by using shifters for shifting a phase of photo light.

Trim patterns on the trim mask form an entire shape of the photoresist image extended to a field region as protecting the defined predetermined part of the image from photo exposure. The photoresist image is a pattern made to form gate pattern.

However, the trim patterns are likely to be recognized as defects during a checking process after fabricating the trim mask, if an interval between the patterns is very narrow on the trim mask.

Hereinafter, the prior art will be described with reference to the accompanying

drawings.

Fig. 1a is a portion of rough diagram of a phase shift mask according to a phase edge phase shift mask of prior art. Referring to Fig. 1a, the phase shift mask(10) has two shifters(20, 20-1). The two shifters(20, 20-1) are phase shift regions where light can be transmitted, and separated in a predetermined interval(1S) on the phase shift mask(10).

Light passing through one of the two shifters(20, 20-1) has a 180-degree phase difference compared to light passing through the other shifter. The phase shift mask(10) is formed by the two shifters(20, 20-1) and a dark part(15). The dark part is formed in chromium for defining the shifters.

Fig. 1b is a rough image pattern of a phase shift mask formed on a semiconductor substrate according to a phase edge phase shift mask of prior art. Referring to Fig. 1b, the phase shift mask(10) of Fig. 1a is overlapped with an active region(27) on a semiconductor substrate(25), wherein the semiconductor substrate(25) is coated by a photoresist(29). And open regions(31, 33) corresponding to the shifters(20, 20-1) of Fig. 1a is formed on the semiconductor substrate(25).

The active region(27) is drawn in dotted lines in order to recognize that the region

is overlapped with the shifters(20, 20-1) of Fig. 1a, and the semiconductor substrate(25) is divided into the part(29) with the photoresist and the parts(31, 33) without the photoresist by photo exposure, corresponding to the shifters(20, 20-1) of Fig. 1a.

Fig. 1c is a portion of rough diagram of a trim mask according to a phase edge phase shift mask of prior art. Referring to Fig. 1c, the trim mask is overlapped with the two shifters(20, 20-1) of Fig. 1a. The two shifters(20, 20-1) formed on the trim mask(35) are drawn in dotted lines in order to understand easily, but the two shifters(20, 20-1) are not formed on the trim mask(35) actually.

In a large way, the trim mask(35) is divided into trim patterns(40, 41, 37, 37-1) where light can not be transmitted and a transparent region(39) where light can be transmitted, and the trim patterns are subdivided into three regions: the one of the three regions is a first trim pattern(40) of a predetermined width of 4W, and formed between the two shifters(20, 20-1); the other is a second trim pattern(41) of predetermined widths of 5W and 8W in horizontal/vertical ways, and formed outside regions composed of the two shifters(20, 20-1); and the anothers are third trim patterns(37, 37-1) of same widths of 3W overlapped with the two shifters(20, 20-1) respectively in left/ right sides, and is in contact with the second trim pattern(41)

The second trim pattern(41) is separated from the shifter(20-1) in a predetermined width of 6W, and the third trim pattern(37-1) is separated inside the shifter(20-1) in a predetermined width of 7W.

That is, the second trim pattern(41) and the third trim pattern(37-1) are separated opposite to each other in a boundary of the shifter(20-1), thereby a notch structure like a check point(1P) is formed.

The notch structure can be recognized as a defect at the check point(1P) in a inspection step after fabricating the trim mask(35). That is, if a width of the notch structure is less than design rule required at the check point(1P), a inspection machine recognize the notch structure as the defect.

A region of the notch structure is overlapped with a portion of the photoresist(29) of Fig. 1b. Furthermore, if light is transmitted through the notch structure of the trim mask(35) during photo exposure, an unwanted field gate image(not shown) is formed by sensitizing the photoresist(29) on the semiconductor substrate(25) of Fig. 1b.

Fig. 1d is a rough image pattern of a trim mask formed on a semiconductor substrate according to a phase edge phase shift mask of prior art. Referring to Fig. 1d, the trim mask(35) of Fig. 1c forms rough images(40-1, 41-1). The one(40-1) of rough images has a predetermined width of 4W-1, and is overlapped with the active region(27). And the other(41-1) has predetermined widths of 8W-1 and 5W-1 in horizontal/vertical ways on the semiconductor substrate(25).

The rough image(41-1) in vertical way is generated by receiving an optical attach through the notch structure on the trim mask(35) of Fig. 1c during the photo exposure. As a result, The rough image(41-1) in vertical way can be disconnected by a subsequent etch process(not shown). Also, The rough image(41-1) can be transferred to a gate of a very small width. The gate increases resistance, and drops a current driving capability. Thereby, the gate deteriorates performance of a semiconductor device.

[Technical Goal of the Invention]

It is therefore an object of the present invention to reduce photoresist loss owing to photo exposure by removing a notch structure formed between trim patterns on a trim mask, forming a region with a predetermined width formed between shifters and a second trim pattern on a field region, and forming a third trim pattern for protecting the

predetermined region, thereby enforcing an image width on the field region.

It is another object of the present invention to reduce photoresist loss owing to photo exposure by removing a notch structure formed between trim patterns within a trim mask, coinciding a side of a second trim pattern on a field region with boundaries of shifters opposite to the second trim pattern, coinciding selected sides of a third trim pattern with the boundaries, and forming a dummy pattern with a predetermined width on an opposite side of the second trim pattern adjacent to the shifters, thereby enforcing an image width on the field region.

[Structure and Operation of the Invention]

To solve the above problems, a phase edge phase shift mask according to one embodiment of the present invention comprises: a plurality of shifters; a phase shift mask composed of an opaque region for defining the shifters; and a trim mask composed of a first to a third trim patterns overlapped with the phase shift mask. The first trim pattern corresponds to an opaque region between the shifters, and the second trim pattern is connected to the first trim pattern separated from at least one shifter in a predetermined width. The third trim pattern is overlapped with the shifters and is adjacent to selected sides of the first and the second trim patterns.

It is desirable that a notch structure is removed by the third trim pattern being in contact with the first and the second trim patterns, and separated region in a predetermined width between the first trim pattern and the second trim pattern is protected by the third trim pattern.

It is more desirable that the shifters are phase shift regions formed to change a phase of incident light, and further have a dummy pattern attached to sides opposite to the selected sides on one side of the second trim pattern.

A phase edge phase shift mask according to one embodiment of the present invention, comprises the steps of: forming a plurality of shifters composed of phase shift regions; forming an opaque region for defining the shifters; preparing a phase shift mask composed of the shifters and the opaque region; forming a first trim pattern corresponding to the opaque region between the shifters; forming a second trim pattern separated from the shifters in a predetermined width; connecting the first trim pattern with the second trim pattern; forming a third trim pattern in contact with selected sides of the first and the second trim patterns, and being overlapped within the shifters; preparing a trim mask where the first to the third trim patterns are formed; and preparing the phase

edge phase shift mask composed of the phase shift mask and the trim mask.

In addition, a phase edge phase shift mask according to another embodiment of the present invention comprises: a plurality of shifters; a phase shift mask composed of an opaque region for defining the shifters; and a trim mask composed of a first to a third trim patterns and a dummy pattern overlapping with the phase shift mask. The first trim pattern corresponds to an opaque region between the shifters, and the second trim pattern is connected to the first trim pattern by being adjacent to at least one shifter. The dummy pattern is attached to a side opposite to a second trim pattern side faced with the shifters. The third trim pattern is adjacent to selected sides of the first and the second trim patterns by overlapping with the shifters.

It is desirable that the third trim pattern removes a notch structure by being adjacent to the first and the second trim patterns, and protects separated regions in a predetermined width between the first and the second trim patterns. The shifters are phase shift regions formed to change a phase of incident light.

A method of fabricating a phase edge phase shift mask according to another embodiment of the present invention, comprises the steps of: forming a plurality of shifters composed of phase shift regions; forming an opaque region for defining the

shifters; preparing a phase shift mask composed of the shifters and the opaque region; forming a first trim pattern corresponding to the opaque region between the shifters; forming a second trim pattern adjacent to the shifters; forming a dummy pattern on an side opposite to a second trim side adjacent to the shifters; connecting the first trim pattern with the second trim pattern; forming a third trim pattern in contact with selected sides of the first and the second trim patterns by being overlapped within the shifters; preparing a trim mask where the first to the third trim patterns are formed; and preparing the phase edge phase shift mask composed of the phase shift mask and the trim mask.

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, the thickness of layers and regions are exaggerated for clarity.

Fig. 2a is a phase edge phase shift mask according to one embodiment of the present invention, illustrating a portion of rough diagram of a trim mask overlapped with shifters. Referring to Fig. 2a, the trim mask(100) is composed of a first and a second trim patterns(150, 160) overlapped with two shifters(105) having the same width of 110W and third trim patterns(120, 140).

Sides of the third trim patterns(120, 140) that are not in contact with the first trim pattern(150) and the second trim pattern(160) is overlapped inside the two shifters(105) as a predetermined width of 100W. The first trim pattern(150) is located between the two shifters(105) and is connected to the second trim pattern(160) formed outside the two shifters(105).

Of the third trim patterns(120, 140), a side of the third trim pattern(140) opposite to the second trim pattern(160) is coincided with a side of the second trim pattern(160).

Fig. 2b is one embodiment according to a phase edge phase shift mask of the present invention, illustrating rough images formed by a phase shift mask and a trim mask on a semiconductor substrate. Referring to Fig. 2b, the rough images(150-1, 160-1) are formed by two consecutive photo exposure processes(not shown) on a semiconductor substrate(200) coated with a photoresist. that is, the rough images(150-1, 160-1) is formed by using two shifters(105) of Fig. 2a drawn in dotted lines and a trim mask(100).

Though the photo exposure process, the rough images(150-1, 160-1) are formed. The one(150-1) of the rough images has a predetermined image of 150W overlapped with an active region(220), and the other(160-1) has predetermined widths of 230W-1 and

shifters; preparing a phase shift mask composed of the shifters and the opaque region; forming a first trim pattern corresponding to the opaque region between the shifters; forming a second trim pattern adjacent to the shifters; forming a dummy pattern on an side opposite to a second trim side adjacent to the shifters; connecting the first trim pattern with the second trim pattern; forming a third trim pattern in contact with selected sides of the first and the second trim patterns by being overlapped within the shifters; preparing a trim mask where the first to the third trim patterns are formed; and preparing the phase edge phase shift mask composed of the phase shift mask and the trim mask.

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, the thickness of layers and regions are exaggerated for clarity.

Fig. 2a is a phase edge phase shift mask according to one embodiment of the present invention, illustrating a portion of rough diagram of a trim mask overlapped with shifters. Referring to Fig. 2a, the trim mask(100) is composed of a first and a second trim patterns(150, 160) overlapped with two shifters(105) having the same width of 110W and third trim patterns(120, 140).

210W-1 in horizontal/ vertical ways on a field region(240). The rough images(150-1, 160-1) are connected on the field region(240).

Compared to Fig. 1d, the rough image(160-1) has been enforced by removing a notch structure on the trim mask(100) of Fig. 2a and horizontally/vertically separating the second trim pattern(160) of Fig. 2a from the shifters(105) in predetermined widths of 190W-1 and 190W.

Except the rough images(150-1, 160-1), the field region(240) on the semiconductor substrate(200) is a part showing photoresist loss owing to photo exposure.

Fig. 2c is comparison data with one embodiment according to a phase edge phase shift mask of the present invention, illustrating a portion of wiring diagram formed by a phase edge phase shift mask of prior art. Referring to Fig. 2c, the wiring diagram shows a portion of the phase edge phase shift mask where a second trim pattern(53) within a trim mask(not shown) is separated from a third trim pattern(49) in a predetermined width of 9W between shifters(45) of a phase shift mask(not shown).

In addition, the wiring diagram(43) can be divided into an upper surface(43) and a

lower surface(B) on the basis of an upper side of the second trim pattern(53).

In the wiring diagram(43), since the second/third trim patterns(53, 49) are separated at the lower surface(B) in a predetermined width of 9W, a region opened to the shifters(45) of the phase shift mask is opened again during photo exposure(not shown) with the use of the trim mask, thereby a photoresist(not shown) protected by the second trim pattern(53) may be lost.

With the photoresist loss, it can reduce an image width formed on field regions(47. 51) smaller than a wiring width during design. Also, it can reduce a gate width after an etching process.

Fig. 2d is comparison data with one embodiment according to a phase edge phase shift mask of the present invention, illustrating an image picture after photo simulation on a phase edge phase shift mask of prior art. Referring to Fig. 2d, with a simulation image(55), it is expected that a photoresist pattern is formed by using the phase edge phase shift mask(not shown) of Fig. 2c on a semiconductor substrate(not shown).

The photo simulation has been operated under conditions of 200nm defocus and

20nm mis-alignment. The phase edge phase shift mask has the second/third trim patterns(53, 49) separated in a predetermined width of 9W like Fig. 2c at a check point(4P).

The simulation image(55) can be expected in the check point(4P) owing to the loss of a photoresist to be protected by the second trim pattern(53), since photo exposure(not shown) is performed through the separated region. The simulation image(55) is nearly disconnected due to two photo exposure processes, and the photoresist does not perform a role of an etching mask in a subsequent etching process.

Fig. 2e is one embodiment according to a phase edge phase shift mask of the present invention, illustrating a portion of wiring diagram formed by the phase edge phase shift mask. Referring to Fig. 2e, the wiring diagram(260) shows a portion of the phase edge phase shift mask where shifter(280) of a phase shift mask(not shown) is overlapped with a second/ a third trim patterns(320, 360) of a trim mask(not shown).

Furthermore, the wiring diagram(260) can be conveniently divided into an upper surface(A) and a lower surface(B) on the basis of an upper side of the second trim pattern(360). The shifter(280) is separated from the second trim pattern(360) in a

predetermined width of 250W, and a photoresist(not shown) leaves in a separated region.

The third trim pattern(320) protects the separated region in the lower surface(B) of the wiring diagram(260), and is adjacent to a boundary of the second trim pattern(360).

In the wiring diagram(260), the photoresist left by the shifter(280) can obtain a big photoresist image, because a left side of the photoresist has been enforced by cutting off photo light with the use of the third trim pattern(320) on the trim mask during photo exposure.

Fig. 2f is one embodiment according to a phase edge phase shift mask of the present invention, illustrating an image picture after photo simulation. Referring to Fig. 2f, with the simulation image(380), it is expected that a photoresist pattern is formed by using the phase edge phase shift mask(not shown) of Fig. 2e on a semiconductor substrate(not shown).

That is, if the phase edge phase shift mask has the second trim pattern(360) and the shifter(280) separated in a predetermined width of 250W like Fig. 2e at a check point(SP), a photoresist is enforced because the third trim pattern(320) protects a

separated region, therefore it is possible to expect the simulation image(380) on a field region of the check point(SP).

The simulation image(380) has the photoresist that a left side is more enforced without losing an upper part of the photoresist, compared to the simulation image(55) of prior art of Fig. 2d.

And, the simulation image(380) can perform a better role of an etching mask for a subsequently proceeding etching process(not shown), compared to prior art. The photo simulation has been operated under conditions of 200nm defocus and 20nm mis-alignment.

Fig. 3a is a phase edge phase shift mask according to another embodiment of the present invention, illustrating a trim mask overlapped with shifters. Referring to Fig. 3a, the trim mask(400) comprises: a first/ a second trim patterns(450, 480) overlapped with two shifters(405, 440) having predetermined widths of 410W and 470W; third trim patterns(420, 460); and a dummy pattern(500).

The phase mask is composed of the two shifters(405, 440), transparent regions,

and an opaque region(not shown) for defining the shifters. Light passing through the shifter(405) has a 180-degree phase difference compared to light passing through the shifter(440) separated at a regular interval.

The trim mask(400) comprises: the first trim pattern(450) having a predetermined width of 450W and corresponding to an active region; and the second trim pattern(480) having predetermined widths of 530W and 510W in horizontal/vertical ways and corresponding to a field region.

The first trim pattern(450) is located between the two shifters(405, 440), and is connected to the second trim pattern(480) formed outside the two shifters(405, 440). The field region indicates region outside the two shifters(405, 440) opening the active region.

Moreover, the trim mask(400) has the second trim pattern(480) adjacent to the two shifter, and attaches the third trim patterns(420, 460) having predetermined widths of 430W and 470W to the first and the second trim patterns(450, 480) in order to remove the notch structure of Fig. 1c.

The third trim patterns(420, 460) are overlapped within the two corresponding shifters(405, 440) in a predetermined width of 400W.

The trim mask(400) has the dummy pattern(500) adjacent to an opposite side of a second trim pattern(480) side faced with the two shifters(405, 440), and the dummy pattern(500) has predetermined widths of 490-1W and 490W in horizontal/vertical ways.

The formation of the dummy pattern(500) does enforce a photoresist image width(not shown) of a field region getting smaller in check points(6P, 7P) due to photo exposure(not shown), and not reduce an image width of the second trim pattern(480) because the two shifters(405, 440) are adjacent to the second trim pattern(480).

Fig. 3b is another embodiment according to a phase edge phase shift mask of the present invention, illustrating rough images formed by a phase shift mask and a trim mask on a semiconductor substrate. Referring to Fig. 3b, the rough images(450-1, 660) are formed in consecutive photo exposure on a semiconductor substrate(600) coated with a photoresist, by using a phase shift mask(not shown) with the shifters(405, 440) shown in dotted lines and the trim mask(400) of Fig. 3a.

In addition, the rough images(450-1, 660) are formed. The one(450-1) of the rough images has a predetermined image width of 450W-1 overlapped with an active

region(620), and the other(660) has predetermined image widths of 570W and 550W in horizontal/ vertical ways on a field region(640). Also, the rough images(450-1, 660) are connected on the field region(640).

Compared to Fig. 1d, the rough image(660) has an enforced image width, by removing the notch structure and attaching the dummy pattern(500) of Fig. 1c within the trim mask(400) of Fig. 3a. Except the rough images(450-1, 660), the field region(640) on the semiconductor substrate(600) shows a loss part of photoresist owing to photo exposure.

Fig. 3c is a phase edge phase shift mask according to another embodiment of the present invention, illustrating a portion of wiring diagram formed by a phase edge phase shift mask. Referring to Fig. 3c, in the wiring diagram(690), shifter(700) on a phase shift mask(not shown) are overlapped with a second/ a third trim patterns(800, 740) on a trim mask(not shown), and the wiring diagram shows a portion of the phase edge phase shift mask attached a dummy pattern(780) to the second trim pattern(800).

Furthermore, the wiring diagram(690) can be conveniently divided into an upper surface(A) and a lower surface(B) on the basis of an upper side of the second trim

pattern(800).

In the lower surface(B) of the wiring diagram(690), the shifter(700) and the third trim pattern(740) are in contact with the second trim pattern(800), and the shifter(700) is overlapped outside the third trim pattern(740) in the upper surface(A) of the wiring diagram(690).

The dummy pattern(780) is in contact with an opposite side of a second trim pattern(800) side faced with the shifters(700).

Fig. 3d is another embodiment according to a phase edge phase shift mask of the present invention, illustrating an image picture after photo simulation. Referring to Fig. 3d, with a simulation image(820), it is expected that a photoresist pattern is formed by using the phase edge phase shift mask(not shown) of Fig. 3c on a semiconductor substrate(not shown).

In the phase edge phase shift mask, if the shifter and the third trim pattern are adjacent to the second trim pattern like Fig. 3c in a check point(8P) and a dummy pattern is attached to one side of the second trim pattern, a photoresist is enforced as much as the

dummy pattern, therefore it is possible to expect the simulation image(820) on a field region of the check point(8P).

The simulation image(820) has the photoresist that is more enforced to the right without losing an upper part of the photoresist, compared to the simulation image(55) of prior art of Fig. 2d. And, the simulation image(820) can perform a better role of an etching mask for a subsequently proceeding etching process(not shown).

The photo simulation has been operated under conditions of 200nm defocus and 20nm mis-alignment.

Like mentioned so far, the phase edge phase shift mask of the present invention can remove a notch structure between trim patterns through one embodiment and another embodiment, protect a region formed by separating the shifters from the second trim pattern in the use of a third trim pattern, and further enforce width of an image of Fig. 2d by attaching a dummy pattern to the second trim pattern.

[Effect of the invention]

Accordingly, the present invention provides a phase edge phase shift mask for reducing photoresist loss due to two exposure processes by controlling overlap intervals between shifters on a phase shift mask and a first to a third trim patterns on a trim mask, and removing a notch structure between trim patterns on the trim mask. As a result, the phase edge phase shift mask can increase a design performance by improving a current driving capability of a semiconductor device.